Univerza v Mariboru

Traffic engineering
Highway Capacity Manual 2010

Uninterrupted traffic flow

Dr. Drago Sever

Content

- Introduction – transportation - traffic eng.
  - Dimensioning process
- HCM 2010 - general
- Uninterrupted traffic flow
  - Freeway (basic segment, ramps, weaving area)
  - Highway, rural roads
- Examples (HCS 2010)

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About me

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Associated professor from the fields
Trans. engineering. and Trans. technology

Director of Institute of transp. sciences
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Subjects:

- Dynamics of traffic flow
- Theory of traffic flow
- Traffic technique I and II
- Transportation technology
- Transportation organization and other.

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Introduction

Transportation - Traffic engineering

- **Transportation (engineering)** is the application of technology and scientific principles to the **planning**, **functional design**, **operation and management of facilities** for any mode of transportation in order to provide for the safe, efficient, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods.

- Transportation engineering is a major component of the logistics, civil engineering and mechanical engineering disciplines.

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Transportation - Traffic engineering

- Transportation engineering, as practiced by civil engineers, primarily involves planning, **design**, construction, maintenance, and operation of transportation facilities.
- **The design aspects** of TE include the sizing of transportation facilities (how many lanes or how much capacity the facility has), determining the materials and thickness used in pavement designing the geometry (vertical and horizontal alignment) of the roadway (or track).
- **Operations and management** involve traffic engineering, so that vehicles move smoothly on the road or track.

Criteria to be meet:

- Land space criteria
- Environmental protected
- Economic criteria
- Urbanistical and architecture requirements
- Legal requirements
- Traffic safety
- **Traffic volumes** → Define relevant operational stage of traffic facility based on existing (planned) traffic volumes and existing (planned) Geometry (in many variants).
- and many other

Introduction

Evaluation of traffic volume (veh/h)

- Maximal hourly traffic volume in average day
  - based on 16. hours traffic counts in average day (normally in cities where no automatic counters exist);
  - based on AADT (K is defined on 300.st peak hour volume)

$$v_{eval} = K \cdot AADT$$

- Morning peak hour volume, afternoon peak hour volume etc.
- Existing traffic volumes, planned traffic volumes, planned traffic volume on the end of planning cycle (norm. 20 years for infrastructure facilities)

$$v_{eval,PC} = q_{eval,today} \cdot (1+r)^{PC}$$ r – growth rate

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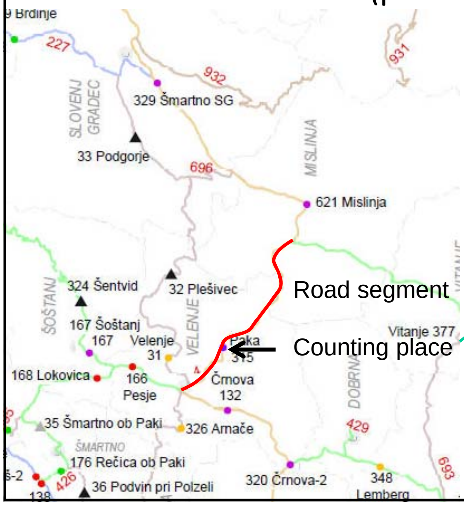
Introduction

- Unique signing system of the state roads
  - each road -> road segment -> counting place
  - traffic volumes (public data)



www.dc.gov.si/promet
(AADT, r, traffic structure)

Hourly distribution: K

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Introduction

Dimensioning process

$$X_i = \frac{V_{eval,i}}{C}$$

Var. / Time	Existing	Var. 1	Var. 2	...	Var. n
Today	$x_0>=1$ $x_0<1$				
Selected time frame	When X=0				
PC	$x_{PC}>=1$ $x_{PC}<1$	$x_{PC}>=1$ No solution	$x_{PC}<1$ Possible solution		$x_{PC}<1$ Possible solution

No additional measuremets are needed

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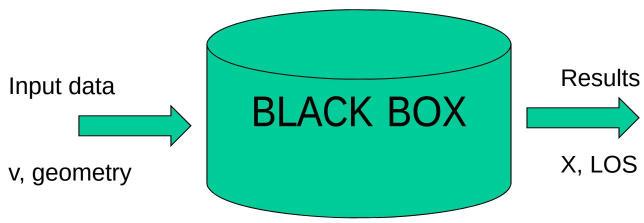
Introduction

Procedures to compute Capacity



Many procedures exist:
- Depends on legislation in different countries
- Depends on different authors (Brillon, Akcelic, …)
- Depend on different software (Sidra, Vissum, HCS, …)
- General accepted procedure (HCM)

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LOS

- Level of Service (LOS) is a way of characterizing the performance of portions of the transportation system
- Traditionally, LOS has only been evaluated for automobiles
- Different ways of calculating LOS exist, but the Highway Capacity Manual (HCM) is most commonly accepted

LOS in HCM

- An indication of quality of service
- LOS "A" through "F"
- F sometimes over capacity, sometimes just miserable conditions
- Based on service measures of effectiveness (MOEs). MOE's vary by chapter
- LOS Score for unmotorised trafic (bikes and pedestrians)
- MMLOS is a combination of LOF for all modes

Introduction

MOEs in HCM

System Element	Service Measures Auto	Pedestrian	Bike	Transit
Freeway Facility	Density	--	--	--
Basic Freeway Segment	Density	--	--	--
Freeway Weaving Segment	Density	--	--	--
Ramp Junction	Density	--	--	--
Multilane Highway	Density	--	Index[a]	--
Two-Lane Highway	% time following, Speed	--	Index[a]	--
Urban Street Facility	Speed	Index[a]	Index[a]	Index[a]
Urban Street Segment	Speed	Index[a]	Index[a]	Index[a]
Signalized Intersection	Delay	Index	Index	--
Two-Way Stop	Delay	--[b]	--	--
All-Way Stop	Delay	--	--	--
Roundabout	Delay	--	--	--
Interchange Ramp Terminal	Delay	--	--	--
Off-Street Ped/Bike Facility	--	Space, Events[c]	Index[a]	--

Notes: (a) See Exhibit 8-3 for the index components.
(b) Not directly calculated; indirectly accounted for by the street crossing delay component of the pedestrian LOS measure for urban street segments.
(c) Events are situations where pedestrians meet bicyclists.

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HCM 2010

Types of analysis in HCM

- Operational: Analyst applies methods directly and **supplies all, or nearly all, of the required model inputs** from actual or forecasted values. The analyses provide the highest level of accuracy but, also require the most-detailed data collection.
- Design: Analyst applies methods to **establish the detailed physical features** that will allow a new or modified roadway to operate at a desired LOS. Design projects are usually targeted for mid- to long-term implementation. Not all the physical features are reflected in the HCM models.
- Planning: In preliminary studies analyst applies methods using **default values for some to nearly all of the model inputs**. The results are less accurate than in an operations analysis, but the use of default values reduces the amount of data collection and the time required to perform an analysis.

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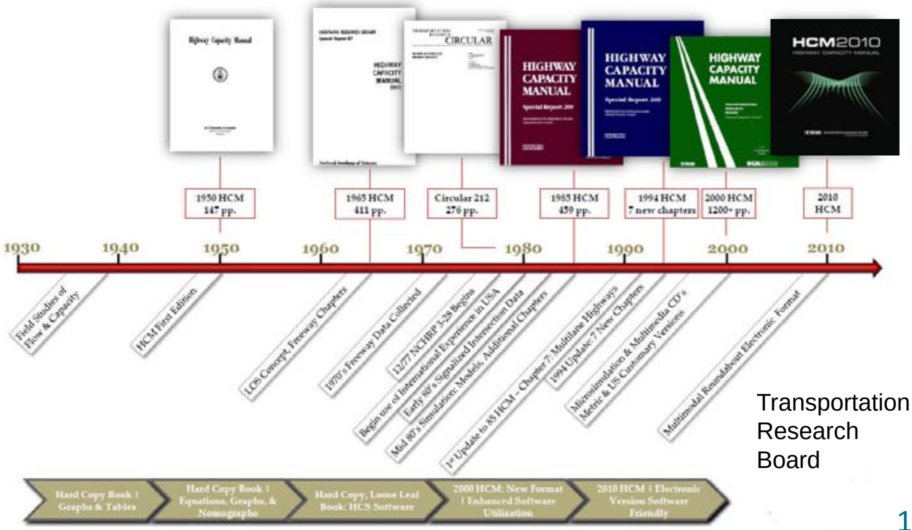
HCM 2010

History of HCM (by TRB)



Transportation Research Board

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HCM 2010

Overview on HCM 2010

- Multimodal approach NEW
- automotive mode (LOS)
- pedestrian, bikes (LOS Score)
- transit mode (LOS)
- Some new methods for different facilities
- All methods are detailed defined in many way (with examples, working sheets)
- implemented in HCS 2010 (McTrans)
- Only in US Customary unit (metric version is on preparation)

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HCM 2010

Organization of HCM

NEW

Volume 1 – Concepts

Volume 2 – Uninterrupted Flow Facilities

Freeways, rural highways, rural roads

Volume 3 – Interrupted Flow Facilities

Urban arterials, intersections, roundabouts
Signals at freeway interchanges,
Bicycle and Pedestrian paths

Volume 4 – Supplemental Materials (Website)

http://www.hcm.trb.org

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HCM 2010

Volume 2: Uninterrupted flow

- Freeways:
  - Chapter 10: Freeway facilities
  - Chapter 11: Basic freeway segments
  - Chapter 12: Freeway weaving segments
  - Chapter 13: Freeway merge and diverge segments
- Multilane highways
  - Chapter 14: Multilane highways
- Two-lane highways
  - Chapter 15: Two-lane highways

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HCM 2010 Freeways

Basic definitions

- **Freeway** is a separated highway with full control of access and two or more lanes in each direction dedicated to the exclusive use of traffic
- **Ramp (freeway merge and diverge segment)** in which two or more traffic stream combine to form a single stream (merge) or single stream divides to form two or more streams (diverge)
- **Weaving segment** in which two or more traffic streams travelled in the same direction (merge in diverge) without traffic signs. Two ramps are connected with by a continous auxiliary lane.

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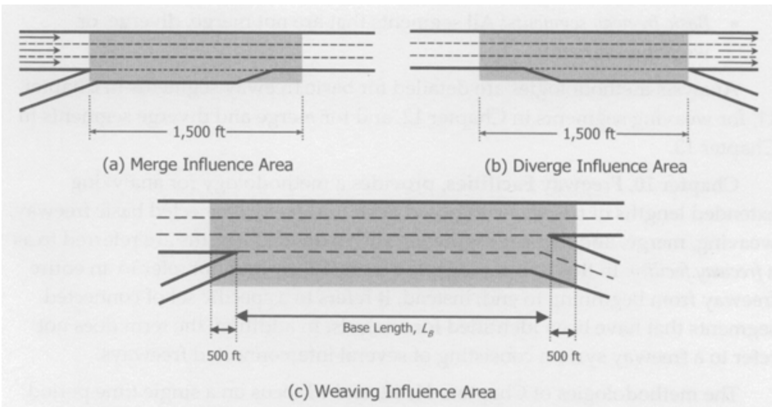
HCM 2010 Freeways

Segments and influence areas



ft = 0,3048 m; 500 ft = 152,4 m

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HCM 2010 Freeways

Major limitations:

- Operation of oversaturated freeway segment (but not necessary oversaturated facility)
- Multiple overlapping breakdowns or bottlenecks
- Conditions where off-ramp queues extend back onto freeway or affect the behavior of exiting vehicle
- Operation of separated high occupancy vehicle (HOV) facilities
- Toll plazas operation
- Operation the segment where free flow speed (FFS) is below 90 km/h or above 120 km/h
- Ramp metering effect

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HCM 2010 Freeways – Basic segment

Basic freeway segment (Ch. 11)

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HCM 2010 Freeways – Basic segment

Basic segment is defined as a segment outside influence of merging, diverging or weaving. Basic segment have a same road and traffic characteristics.

- Base conditions:
  - Include good weather, good visibility, no incident or accident, no work zone activities and no pavement deterioration serious enough to affect operations
  - No heavy vehicle in the traffic stream
  - Minimum 12 ft (3,658 m) lane width and 6 ft (1,829 m) righ - side clearance
  - A driver population composed primarily of regular users who are familiar with the facility

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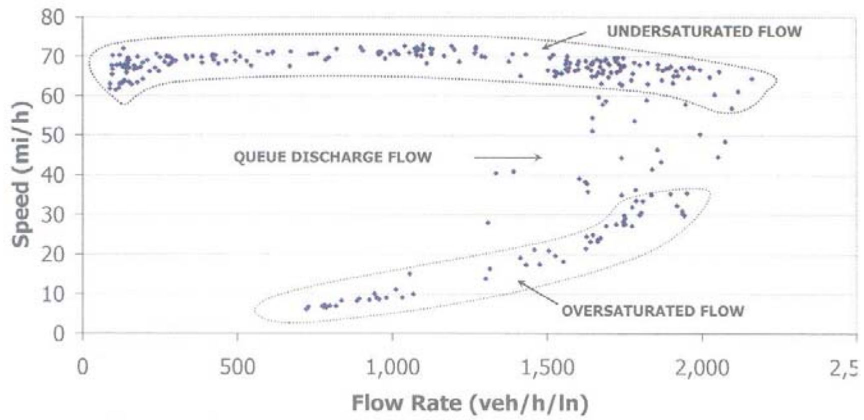
HCM 2010 Freeways – Basic segment

Flow characteristics under base conditions



Note: I-405, Los Angeles, Calif.

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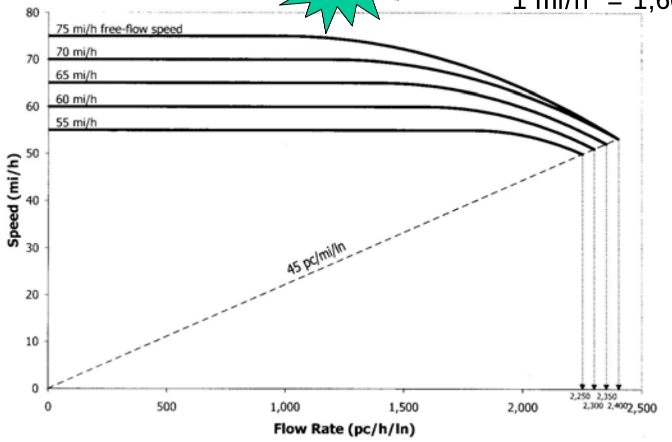
HCM 2010 Freeways – Basic segment

Speed – flow curves under base conditions

NEW

1 mi/h = 1,609334 km/h



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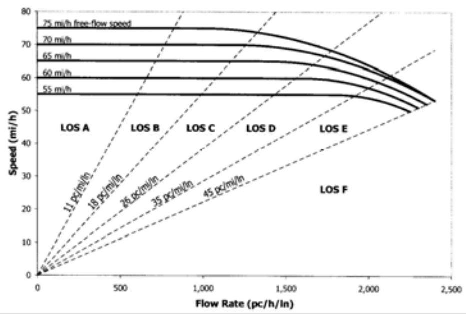
HCM 2010 Freeways – Basic segment

Capacity under base conditions

- Mainly depends on Free flow speed and varies between 2400 (120 km/h) and 2250 pc/h/line (90 km/h)
- More lines in one direction => x number ob lanes
- Reached by density D = 28 pc/km/line (45 pc/mi/line)



Quality of traffic operations is described by level of service (LOS), where MOE is density of traffic flow.

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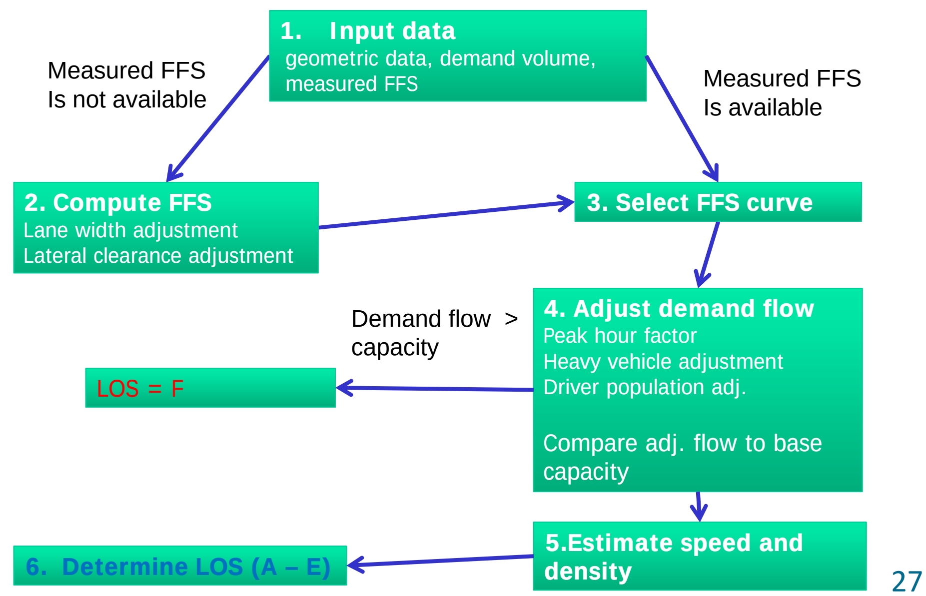
HCM 2010 Freeways – Basic segment - Methodology



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HCM 2010 Freeways – Basic segment

2. Compute FFS

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22\,TRD^{0.84} \quad \text{(mi/h)}$$

Total ramp density 3 mi left and right from analyzing cross section

Average Lane Width (ft)	Reduction in FFS, f_{LW} (mi/h)
≥12	0.0
≥11–12	1.9
≥10–11	6.6

Right-Side Lateral Clearance (ft)	Lanes in One Direction: 2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

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HCM 2010 Freeways – Basic segment

5. Estimate speed and density
6. Determine LOS

only valid when v/C <= 1

LOS	Density (pc/mi/ln)
A	≤11
B	>11–18
C	>18–26
D	>26–35
E	>35–45
F	Demand exceeds capacity >45

$D = \frac{v_p}{S}$ (pc/mi/lane)

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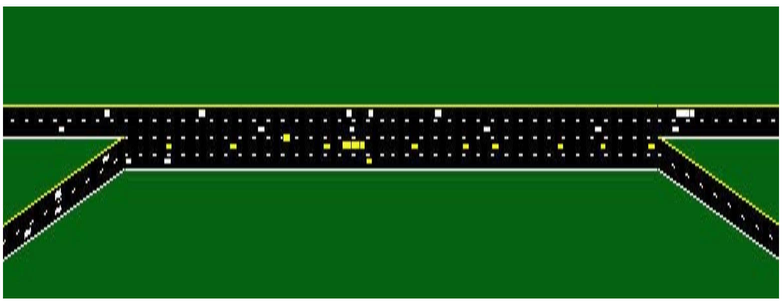
HCM 2010 Freeways – Freeway weaving segment

Freeway weaving segment (Ch. 12)



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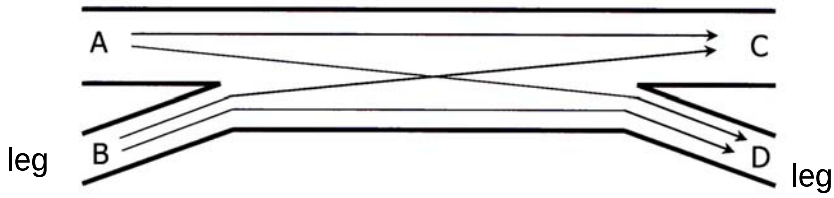
HCM 2010 Freeways – Weaving segments

weaving / nonweaving movements



Geometry characteristics:
-Length
-Width
-Configuration

Require special attention when driving through

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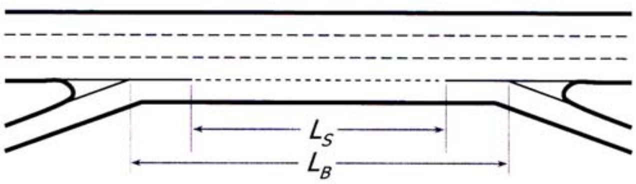
HCM 2010 Freeways – Weaving segments

Length and width

1 ft = 0,3048 m



Ls (ft) – short length, distance between the end points of any barrier marking that prohibit lane changing

Lb (ft) – base length, distance between points in the respective gore area where the left edge of the ramp and right edge of freeway meet.

On average Ls=0,77 Lb, exceptionally Ls=Lb

Influence are: 500 ft left and right on the freeway

Width depend on the number of lanes in weaving area cross section and configuration.

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HCM 2010 Freeways – Weaving segments

Configuration of weaving segments

It is refers to way that entry and exit lanes are linked. The configuration determine how many lanes changes a weaving driver must make to complete the weaving maneuver successfully.

Types of configuration: one-sided and two-sided.

NEW

Configuration parameters:

- LCrf – min. number of lane changes that ramp to freeway weaving vehicle must make to complete maneuver successfully,
- LCfr – min. number of lane changes that freeway to ramp weaving vehicle must make to complete maneuver successfully,
- Nwl – number of lanes which a weaving maneuver may be completed with one lane change or no lane change

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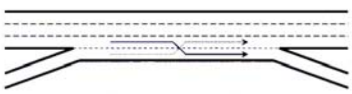
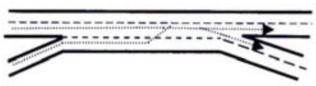
HCM 2010 Freeways – Weaving segments

One-sided and two-sided segments

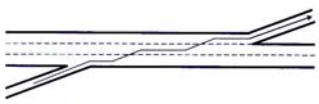


(a) One-Sided Ramp Weave

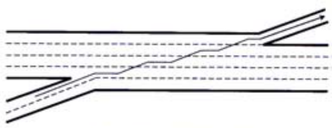


(b) One-Sided Major Weave

No weaving maneuver require more than two lane changes to be completed successfully



(a) Two-Sided Weaving Section with Single-Lane Ramps



(b) Two-Sided Weaving Section with Three Lane Changes

At least one weaving maneuver requires three or more lane changes to be complete successfully

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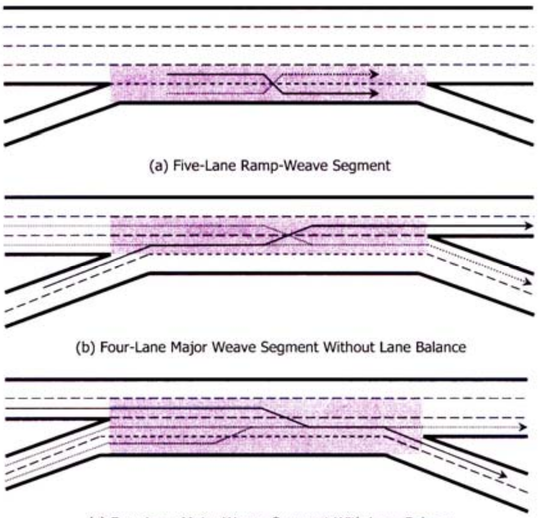
HCM 2010 Freeways – Weaving segments

Configuration parameters



(a) Five-Lane Ramp-Weave Segment

(b) Four-Lane Major Weave Segment Without Lane Balance

(c) Four-Lane Major Weave Segment With Lane Balance

LCrf = 1
LCfr = 1
Nwl = 2

LCrf = 1
LCfr = 0
Nwl = 2

LCrf = 0
LCfr = 1
Nwl = 3

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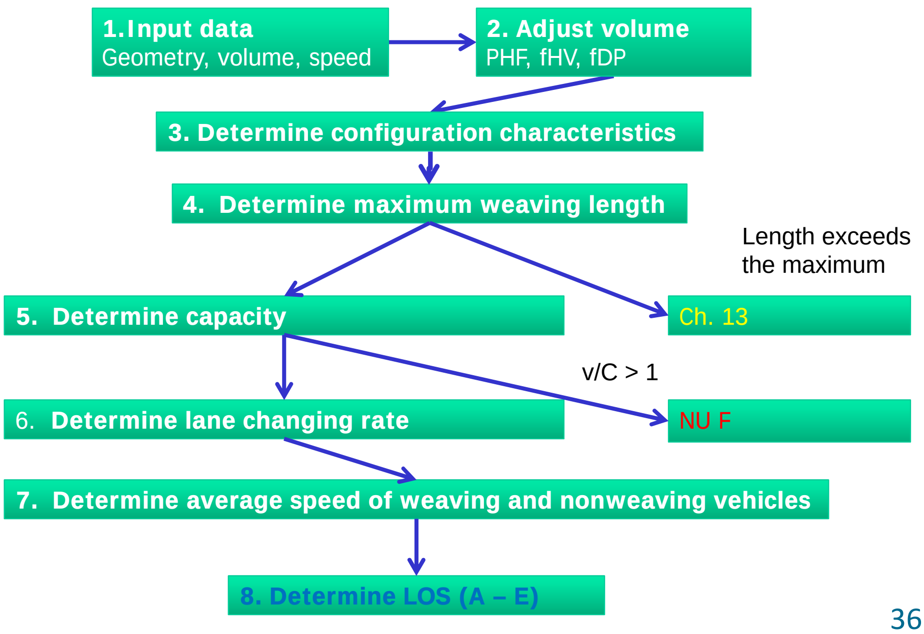
HCM 2010 Freeways – Weaving segments - Methodology



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HCM 2010 Freeways – Weaving segments

3. Determine configuration char.

Determine minimum rate at which weaving vehicles must change lane to complete all weaving maneuvers successfully - LCmin:

- One-sided weaving segments:

$$LC_{MIN} = (LC_{RF} \times v_{RF}) + (LC_{FR} \times v_{FR}) \quad \text{(lc/h)}$$

Nwl = 2 ali 3

- Two-sided weaving segments:

$$LC_{MIN} = LC_{RR} \times v_{RR} \quad \text{(lc/h)}$$

Nwl = 0

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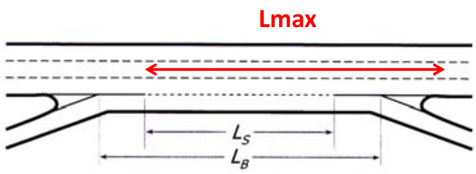
HCM 2010 Freeways – Weaving segments

4. Determine max. weaving length



Lmax is a length at which weaving turbulence no longer has an impact on operation within the segment (capacity).

$$L_{MAX} = \left[5{,}728(1+VR)^{1.6}\right] - \left[1{,}566 N_{WL}\right] \quad \text{(ft)}$$

Volume ratio by one-sided segments:

$$VR = \frac{v_w}{v} = \frac{v_w}{v_w + v_{Nw}} = \frac{v_{RF} + v_{FR}}{(v_{RF} + v_{FR}) + (v_{RR} + v_{FF})}$$

If Ls >= Lmax – analyze merge and diverge junctions as separate segments by using methodology in Ch. 13.

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HCM 2010 Freeways – Weaving segments

5. Determine capacity

- By density: based on reaching a density of 43 pc/mi/ln

$$c_{IWL} = c_{IFL} - [438.2(1+VR)^{1.6}] + [0.0765 L_S] + [119.8 N_{WL}]$$

$$c_W = c_{IWL} N f_{HV} f_p \quad \text{(pc/h)}$$

- By demand flows: capacity is defined:

$$c_{IW} = \frac{2{,}400}{VR} \quad \text{for } N_{WL} = 2 \text{ lanes}$$

$$c_{IW} = \frac{3{,}500}{VR} \quad \text{for } N_{WL} = 3 \text{ lanes}$$

$$c_W = c_{IW} f_{HV} f_p \quad \text{(pc/h)}$$

Smaller value of capacity is used.

v/C ratio:

$$v/c = \frac{v f_{HV} f_p}{c_W}$$

v/C > 1 => **NU F**

v/C < 1 => NU A - E

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HCM 2010 Freeways – Weaving segments

7. Determine average speed
8. Determine LOS

$$S = \frac{v_W + v_{NW}}{\left(\frac{v_W}{S_W}\right) + \left(\frac{v_{NW}}{S_{NW}}\right)} \quad \text{(mi/h)}$$

$$D = \frac{\left(\frac{v}{N}\right)}{S} \quad \text{(pc/mi/ln)}$$

LOS	Density (pc/mi/ln) Freeway Weaving Segments	Density (pc/mi/ln) Weaving Segments on Multilane Highways or C-D Roadways
A	0–10	0–12
B	>10–20	>12–24
C	>20–28	>24–32
D	>28–35	>32–36
E	>35	>36
F	Demand exceeds capacity	

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Freeway merge and diverge segments (Ch. 13)

Classification of ramps

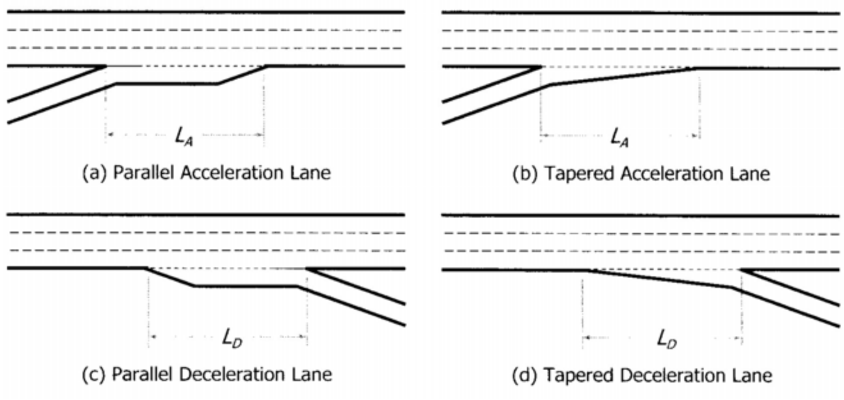
- Freeway junctions:
  - Ramp-freeway junction – merge: on-ramp, diverge: off-ramp,
  - Merging two major facilities: main merge junction,
  - Diverge two major facilities: main diverge junction;
- Majority of ramps are right-hand ramp – join from the right, some are left-hand ramp;
- They may have one or two lanes. Before merging with freeway two lanes join into one acceleration on-ramp;
- Merge and diverge operations are affected by the size of freeway segment into one direction.

Ramp influence area

(450 m)

Also impact onto neighbors junctions.

Acceleration – deceleration lane

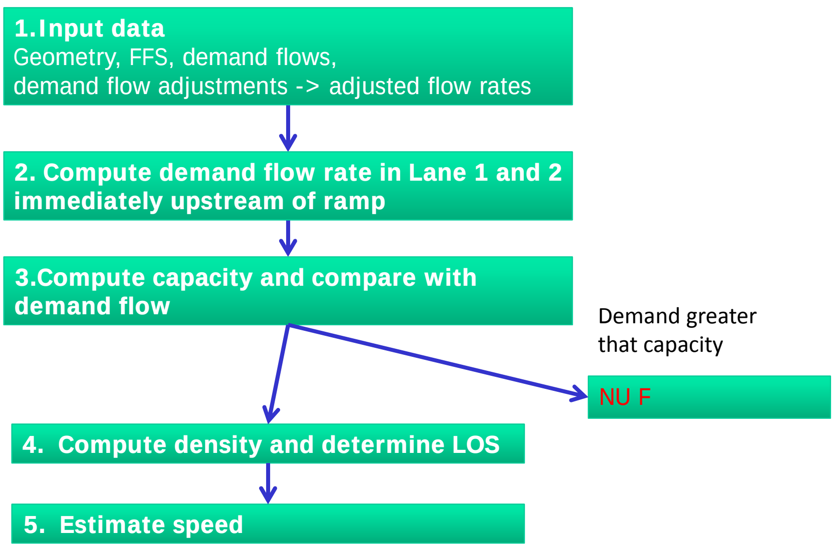


Criteria for define LOS

The criteria for defining LOS is average density of traffic flow at the ramp:

LOS	Density (pc/mi/ln)	Comments
A	≤10	Unrestricted operations
B	>10–20	Merging and diverging maneuvers noticeable to drivers
C	>20–28	Influence area speeds begin to decline
D	>28–35	Influence area turbulence becomes intrusive
E	>35	Turbulence felt by virtually all drivers
F	Demand exceeds capacity	Ramp and freeway queues form

HCM 2010 Freeways – Ramps - Methodology



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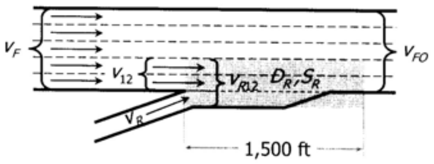
HCM 2010 Freeways – Merge an diverge segments

2. Estimate v12

On-ramps:



$$v_{12} = v_F \times P_{FM} \quad \text{(pc/h)}$$

No. of Freeway Lanes[a]	Model(s) for Determining P_{FM}
4	$P_{FM} = 1.000$
6	$P_{FM} = 0.5775 + 0.000028\, L_A$
	$P_{FM} = 0.7289 - 0.0000135\,(v_F + v_R) - 0.003296 S_{FR} + 0.000063 L_{UP}$
	$P_{FM} = 0.5487 + 0.2628\,(v_D / L_{DOWN})$
8	For $v_F / S_{FR} \le 72$: $P_{FM} = 0.2178 - 0.000125 v_R + 0.01115\,(L_A / S_{FR})$
	For $v_F / S_{FR} > 72$: $P_{FM} = 0.2178 - 0.000125 v_R$

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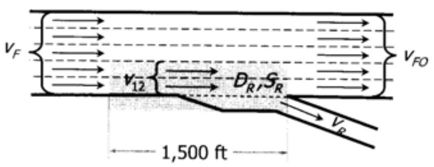
HCM 2010 Freeways – Merge an diverge segments

2. Estimate v12

Off-ramps:



$$v_{12} = v_R + (v_F - v_R) P_{FD} \quad \text{(pc/h)}$$

No. of Freeway Lanes[a]	Model(s) for Determining P_{FD}
4	$P_{FD} = 1.000$
6	$P_{FD} = 0.760 - 0.000025 v_F - 0.000046 v_R$
	$P_{FD} = 0.717 - 0.000039 v_F + 0.604 (v_U / L_{UP})$
	$P_{FD} = 0.616 - 0.000021 v_F + 0.124 (v_D / L_{DOWN})$
8	$P_{FD} = 0.436$

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HCM 2010 Freeways – Merge an diverge segments

3. Estimate the capacity

FFS (mi/h)	Capacity of Upstream/Downstream Freeway Segment[a] — No. of Lanes in One Direction: 2	3	4	>4	Max. Desirable Flow Rate (v_{R12}) Entering Merge Influence Area[b]	Max. Desirable Flow Rate (v_{12}) Entering Diverge Influence Area[b]
≥70	4,800	7,200	9,600	2,400/ln	4,600	4,400
65	4,700	7,050	9,400	2,350/ln	4,600	4,400
60	4,600	6,900	9,200	2,300/ln	4,600	4,400
55	4,500	6,750	9,000	2,250/ln	4,600	4,400

Notes: [a] Demand in excess of these capacities results in LOS F.
[b] Demand in excess of these values alone does not result in LOS F; operations may be worse than predicted by this methodology.

Ramp FFS S_{FR} (mi/h)	Capacity of Ramp Roadway: Single-Lane Ramps	Capacity of Ramp Roadway: Two-Lane Ramps
>50	2,200	4,400
>40–50	2,100	4,200
>30–40	2,000	4,000
≥20–30	1,900	3,800
<20	1,800	3,600

Note: Capacity of a ramp roadway does not ensure an equal capacity at its freeway or other high-speed junction. Junction capacity must be checked against criteria in Exhibit 13-8 and Exhibit 13-9.

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HCM 2010 Freeways – Merge an diverge segments

4. Estimate density and LOS

On ramps:

$$D_R = 5.475 + 0.00734 v_R + 0.0078 v_{12} - 0.00627 L_A \quad \text{(pc/mi/ln)}$$

Off ramps:

$$D_R = 4.252 + 0.0086 v_{12} - 0.009 L_D \quad \text{(pc/mi/ln)}$$

LOS	Density (pc/mi/ln)	Comments
A	≤10	Unrestricted operations
B	>10–20	Merging and diverging maneuvers noticeable to drivers
C	>20–28	Influence area speeds begin to decline
D	>28–35	Influence area turbulence becomes intrusive
E	>35	Turbulence felt by virtually all drivers
F	Demand exceeds capacity	Ramp and freeway queues form

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Two-lane highways (Ch. 15)

Introduction

- The most common type of roads; one lane in each direction, passing maneuver,

- Functions: efficient mobility – connection major trip destinations, accessibility to remote populated area, serve recreation areas, small towns, rural areas and community,

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Classification

- Class I: where motorists expect to travel at relatively high speed. Are major intercity routes and primary connector of major traffic generators. Long distance trips.
- Class II: where motorists not necesary expect to travel at high speed. Access route to Class I, recreational routes, pass throught rugged terrain. Serve relative short trips
- Class III: serving moderately developed areas. Local traffic mixed with trought traffic, density of acess points, Reduced speed limits reflect the higher activity level.

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Capacity

Capacity of two lane highway under base condition is 1700 pc/h in one direction with max. 3200 pc/h in both direction.

Base condition:

- Lane width >= 12 ft (3,658 m)
- Clear shoulders >= 6 ft (1,829 m)
- No no-passing zones,
- All passenger cars in the traffic stream,
- Level terrain
- No impediments to through traffic (traffic signals, turning veh.)

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LOS (automobile mode)

- Average travel speed (ATS) reflects mobility.
- Percent time-spending-following (PTSF) reflects the freedom of maneveur and the comfort and convenience of travel.
- Percent of free-flow speed (PFFS) represents the ability of vehicles to travel at or near the posted speed limit.

1 mi/h = 1,609 km/h

LOS	Class I Highways ATS (mi/h)	Class I Highways PTSF (%)	Class II Highways PTSF (%)	Class III Highways PFFS (%)
A	>55	≤35	≤40	>91.7
B	>50–55	>35–50	>40–55	>83.3–91.7
C	>45–50	>50–65	>55–70	>75.0–83.3
D	>40–45	>65–80	>70–85	>66.7–75.0
E	≤40	>80	>85	≤66.7

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LOS (bicycle mode)

- Average effective width of the outside through lane
- Motorized vehicle volumes
- Motorized vehicle speed
- Heavy vehicle (trucks) volumes
- Pavement condition

LOS	BLOS Score
A	≤1.5
B	>1.5–2.5
C	>2.5–3.5
D	>3.5–4.5
E	>4.5–5.5
F	>5.5

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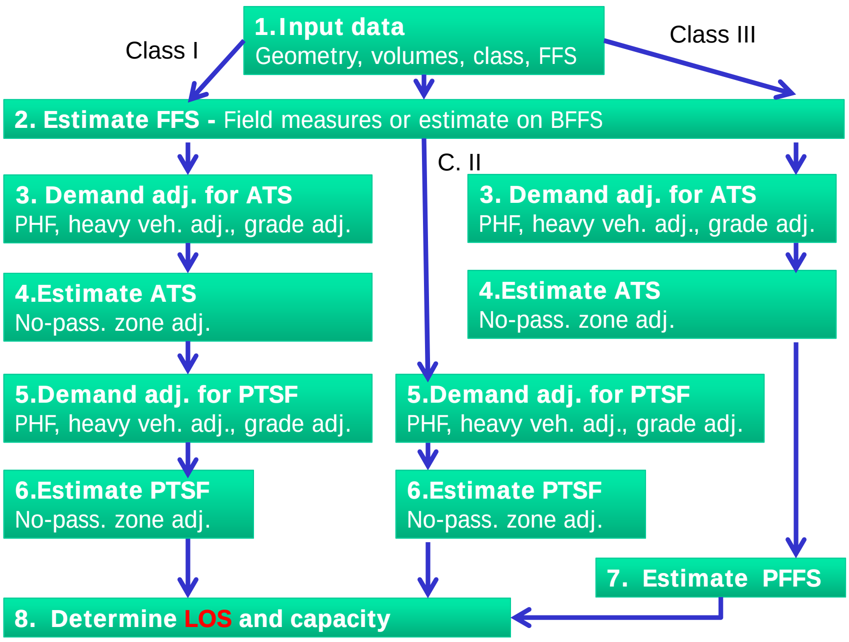
HCM 2010 Two-lane highways – Methodology – Automobile



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2. Estimate FFS

1 mi/h = 1,609 km/h

Measurement:

Low traffic – 100 veh. in each dir.

$$FFS = S_{FM} + 0.00776\left(\frac{v}{f_{HV,ATS}}\right) \quad \text{(mi/h)}$$

Average measured speed (mi/h)

Heavy veh. adj.

Estimate:

Max. speed allowed (mi/h)

$$FFS = BFFS - f_{LS} - f_A \quad \text{(mi/h)}$$

Lane Width (ft)	Shoulder Width (ft) ≥0 <2	≥2 <4	≥4 <6	≥6
≥9 <10	6.4	4.8	3.5	2.2
≥10 <11	5.3	3.7	2.4	1.1
≥ 11 <12	4.7	3.0	1.7	0.4
≥12	4.2	2.6	1.3	0.0

Access Points per Mile (Two Directions)	Reduction in FFS (mi/h)
0	0.0
10	2.5
20	5.0
30	7.5
40	10.0

Note: Interpolation to the nearest 0.1 is recommended.

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HCM 2010 Two-lane highways

3. Demand adj. for ATS

for C. I and III only

$$v_{i,ATS} = \frac{V_i}{PHF \times f_{g,ATS} \times f_{HV,ATS}} \quad \text{(pc/h)}$$

Heavy veh. adj. factor

$$f_{HV,ATS} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

Grade adj. factor:

-Extended segments (>= 2 mi) of level terrain

-Extended segments (>= 2 mi) of rolling terrain

-Specific upgrades (depends on length, grade and directional volume)

-Specific downgrades (any grade of 3% or steeper and 0,6 mi (800 m) or longer)

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4. Estimate the ATS

for C. I and III only

1 mi/h = 1,609 km/h

$$ATS_d = FFS - 0.00776(v_{d,ATS} + v_{o,ATS}) - f_{np,ATS} \quad \text{(mi/h)}$$

Opposing Demand Flow Rate, v_o (pc/h)	Percent No-Passing Zones ≤ 20	40	60	80	100
FFS ≥ 65 mi/h					
≤100	1.1	2.2	2.8	3.0	3.1
200	2.2	3.3	3.9	4.0	4.2
400	1.6	2.3	2.7	2.8	2.9
600	1.4	1.5	1.7	1.9	2.0
800	0.7	1.0	1.2	1.4	1.5
1,000	0.6	0.8	1.1	1.1	1.2
1,200	0.6	0.8	0.9	1.0	1.1
1,400	0.6	0.7	0.9	0.9	0.9
≥1,600	0.6	0.7	0.7	0.7	0.8
FFS = 60 mi/h					
≤100	0.7	1.7	2.5	2.8	2.9
200	1.9	2.9	3.7	4.0	4.2
400	1.4	2.0	2.5	2.7	3.9
600	1.1	1.3	1.6	1.9	2.0
800	0.6	0.9	1.1	1.3	1.4
1,000	0.6	0.7	0.9	1.1	1.2
1,200	0.5	0.7	0.9	0.9	1.1
1,400	0.5	0.6	0.8	0.8	0.9
≥1,600	0.5	0.6	0.7	0.7	0.7
FFS = 55 mi/h					
≤100	0.5	1.2	2.2	2.6	2.7
200	1.5	2.4	3.5	3.9	4.1
400	1.3	1.9	2.4	2.7	2.8
600	0.9	1.1	1.6	1.8	1.9
800	0.5	0.7	1.1	1.2	1.4
1,000	0.5	0.6	0.8	0.9	1.1
1,200	0.5	0.6	0.7	0.9	1.0
1,400	0.5	0.6	0.7	0.7	0.9
≥1,600	0.5	0.6	0.6	0.6	0.7

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6. Estimate PTSF

for C. I and II only

$$PTSF_d = BPTSF_d + f_{np,PTSF}\left(\frac{v_{d,PTSF}}{v_{d,PTSF} + v_{o,PTSF}}\right)$$

$$BPTSF_d = 100\left[1 - \exp\left(a v_d^b\right)\right]$$

Opposing Demand Flow Rate, v_o (pc/h)	Coefficient *a*	Coefficient *b*
≤200	-0.0014	0.973
400	-0.0022	0.923
600	-0.0033	0.870
800	-0.0045	0.833
1,000	-0.0049	0.829
1,200	-0.0054	0.825
1,400	-0.0058	0.821
≥1,600	-0.0062	0.817

Note: Straight-line interpolation of *a* to the nearest 0.0001 and *b* to the nearest 0.001 is recommended.

Opposing Demand Flow Rate, v_o (pc/h)	Percent No-Passing Zones				
	≤ 20	40	60	80	100
FFS ≥ 65 mi/h					
≤100	1.1	2.2	2.8	3.0	3.1
200	2.2	3.3	3.9	4.0	4.2
400	1.6	2.3	2.7	2.8	2.9
600	1.4	1.5	1.7	1.9	2.0
800	0.7	1.0	1.2	1.4	1.5
1,000	0.6	0.8	1.1	1.1	1.2
1,200	0.6	0.8	0.9	1.0	1.1
1,400	0.6	0.7	0.9	0.9	0.9
>1,600	0.6	0.7	0.7	0.7	0.8
FFS = 60 mi/h					
≤100	0.7	1.7	2.5	2.8	2.9
200	1.9	2.9	3.7	4.0	4.2
400	1.4	2.0	2.5	2.7	3.9
600	1.1	1.3	1.6	1.9	2.0
800	0.6	0.9	1.1	1.3	1.4
1,000	0.6	0.7	0.9	1.1	1.2
1,200	0.5	0.7	0.9	0.9	1.1
1,400	0.5	0.6	0.8	0.8	0.9
>1,600	0.5	0.6	0.7	0.7	0.7
FFS = 55 mi/h					
≤100	0.5	1.2	2.2	2.6	2.7
200	1.5	2.4	3.5	3.9	4.1
400	1.3	1.9	2.4	2.7	2.8
600	0.9	1.1	1.6	1.8	1.9
800	0.5	0.7	1.1	1.2	1.4
1,000	0.5	0.6	0.8	0.9	1.1
1,200	0.5	0.6	0.7	0.9	1.0
1,400	0.5	0.6	0.7	0.7	0.9
≥1,600	0.5	0.6	0.6	0.6	0.7

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6. Estimate PFFS

for C. III only

$$PFFS = \frac{ATS_d}{FFS}$$

7. Estimate LOS and capacity

LOS:

Class I: ATS in PTSF (worst of)
Class II : PTSF
Class III: PFFS

Capacity:

$$c_{dATS} = 1{,}700\, f_{g,ATS}\, f_{HV,ATS}$$

$$c_{dPTSF} = 1{,}700\, f_{g,PTSF}\, f_{HV,PTSF}$$

Class I: lower of both
Class II : on PTSF
Class III: on ATS

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HCM 2010 Two-lane highways – Methodology – Bicycle

1. Input data
Geometry, volumes, speed limit, on highway parking, pavement

2. Calculate the directional flow rate in the outside lane

3. Calculate the effective width

4. Calculate the effective speed factor
Speed limit

5. Determine LOS
BLOS score

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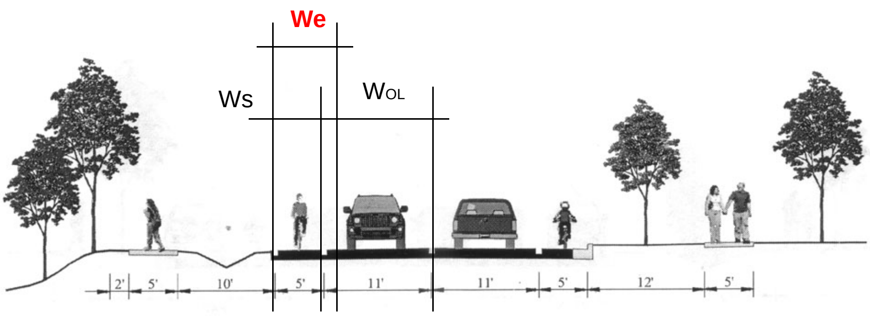
HCM 2010 Two-lane highways – Bicycle

3. Determine the effective width

1 ft = 0,304 m



Configuration #5e - New Sidewalk & No Parking on South Side, Widened Lawn Extension on North Side
TOTAL PAVED WIDTH - 32'

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HCM 2010 Two-lane highways – Bicycle

3. Determine the effective width

1 ft = 0,304 m

If W_s is greater than or equal to 8 ft:

$$W_e = W_v + W_s - (\%OHP \times 10\text{ ft})$$

If W_s is greater than or equal to 4 ft and less than 8 ft:

$$W_e = W_v + W_s - 2 \times (\%OHP(2\text{ ft} + W_s))$$

If W_s is less than 4 ft:

$$W_e = W_v + (\%OHP(2\text{ ft} + W_s))$$

with, if V is greater than 160 veh/h:

$$W_v = W_{OL} + W_s$$

Otherwise,

$$W_v = (W_{OL} + W_s) \times (2 - 0.005V)$$

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HCM 2010 Two-lane highways – Bicycle

5. Determine the LOS

Effective speed factor

$$S_t = 1.1199\ln(S_p - 20) + 0.8103$$

$$BLOS = 0.507\ln(v_{OL}) + 0.1999S_t(1 + 10.38HV)^2 + 7.066(1/P)^2 - 0.005(W_e)^2 + 0.057$$

Percentage of heavy vehicle

Average effective with for bikes

FHWA 5-point pavement surface condition rating

LOS	BLOS Score
A	≤1.5
B	>1.5–2.5
C	>2.5–3.5
D	>3.5–4.5
E	>4.5–5.5
F	>5.5

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Conclusion

- Questions?

THANKS FOR YOUR ATTENTION!

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